Data interchange standards in healthcare: semantic interoperability in preoperative assessment
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Chapter 1

Introduction
1. Introduction

Although patient information systems have the potential to improve the quality of care [1, 2] they have not been marketed on a large scale yet and they slowly become part of practices of physicians [3-5]. Capital requirements, technical issues, problems concerning data interchange standards and high maintenance costs are the primary barriers for implementation [4, 5]. Studies showed that adoption of patient information systems in some fields like anesthesia, comprising perioperative care, is much less than in others [4, 6-9]. A major difference between an anesthesia information management system (AIMS) and most other patient information system products is that extensive communication with diverse monitors, acquiring real-time patient data, is required. The AIMS may receive information from patient information subsystems or modules, from patient-connected devices, and from the anesthesiologist. Thus, it is important that an AIMS is integrated with the patient information system and interacts with other devices and their systems to ensure seamless and paperless flow of information and optimal patient care [6, 9].

This interaction requires both a standardized data model (structure) and standardized terminology (content). One barrier at the moment is that AIMS configuration often includes the development of a customized set of terms and phrases to be used in the department where it is installed. This lack of standardization of terms in AIMS inhibits the sharing of data even with AIMS from the same vendor at different institutions [9]. Moreover, the use of simple taxonomies is insufficient to allow secondary uses such as complex data mining and knowledge discovery. The data that are collected as part of the anesthesia record, when combined with information from other sources, can be an important resource for delivering the best care to the patient. However, as these data are used outside of their source, their meaning must remain unambiguous. Increasingly, data sharing is likely to transcend national borders, so that the chosen standards must have both an international and a national perspective [6]. The Health Level 7 (HL7) Reference Information Model (RIM) and the Systematized Nomenclature of Medicine-Clinical Terms (SNOMED CT) are used by the international community as standard information model and standard terminology.

The main focus of this thesis is on standardization of the content of AIMS by using terminological systems, especially on using SNOMED CT as a standard reference terminological system in the preoperative assessment part of AIMS.

1.1. Preoperative assessment

Preoperative assessment is a check-up before having surgery to see if there is anything that puts patients at high risk for complications around the time of the surgery [10]. The more co-morbid conditions a patient has, the higher the risk for perioperative complications [10]. A detailed evaluation of a patient's health condition during preoperative assessment makes physicians and nurses aware of any potential problem that could occur in the perioperative or postoperative phase of surgery [11]. The purpose of this evaluation is to estimate and reduce the mortality and morbidity associated with surgery, to determine required anesthesia and equipment during operation based on the patient’s condition, to increase
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quality of care, to inform the patient about anesthesia, and to obtain informed consent [12, 13]. A proper preoperative assessment also contributes to the reduction of postoperative incidents and late surgery cancellation and a better determination of postoperative care [14, 15]. A study published in 2000 showed that inadequate preoperative assessment was the cause of around 40% of the deaths attributed to anesthesia in Australia [16]. It was also reported that the mortality rate in patients who had an inadequate preoperative assessment was 6 times higher than in patients who had been assessed properly [16].

All patients scheduled for surgery should be considered for preoperative assessment. Depending on the patient’s condition different healthcare providers may be involved in the assessment. For very low-risk procedures, such as dental extractions or cataract surgery, the assessment may only involve the oral surgeon or ophthalmologist confirming the absence of significant risk factors [10]. In some healthcare settings the preoperative assessment is done by a nurse consulting with an anesthesiologist when needed. For more complex procedures, evaluation by a physician experienced in preoperative assessment or an anesthesiologist may be judicious. Depending on the patient’s condition it is sometimes necessary to consult other specialists to obtain information [13]. For carrying out the preoperative assessment in the past every patient was normally admitted to the hospital a day before surgery. The assessment was done on the day before surgery resulting in inappropriate patient optimization for the surgery as healthcare providers might not have enough time to manage some patient conditions before surgery. This resulted in many surgery cancellations [17]. Nowadays, an increasing number of patients are evaluated in preoperative assessment clinics [18]. The assessment is often done some days or weeks before surgery by an anesthesiologist, not necessarily the one that will provide anesthesia, or collaboratively by other healthcare providers [19]. This provides required time for healthcare providers to optimize patient conditions before surgery. However, this results in decreased personal contact between the actual anesthesia care provider and the patient. Consequently, this situation and such a multidisciplinary setting require an increasing reliance on information that is obtained during the preoperative assessment: one should have access to detailed and ‘objective’ information right before surgery without the need to perform parts or all of a preoperative assessment again. To share the collected data during preoperative assessment among different healthcare providers and different settings standardization of these data is required.

1.2. Standardization

A high-priority challenge for medical informatics is interoperability of patient information systems. Interoperability with regard to a specific task is said to exist between two applications when one application can accept data (including data in the form of a service request) from the other and perform the task in an appropriate and satisfactory manner (as judged by the user of the receiving system) without the need for extra operator intervention. Interoperability involves many methodological and practical aspects and requires the creation, acceptance, and implementation of clinical data standards to ensure that data contained in a patient information system is available and meaningful to other information systems. It depends upon two important concepts: syntax and semantics [20, 21]. Syntax
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refers to the structure of communication (among which the information model) and semantics is about the meaning of the communicated data. Information models allow transactions to flow consistently between systems or organizations because they contain instructions (or specifications) of format, data elements, and structure. Semantic interoperability requires unique codes for clinical concepts such as diseases, problem lists, allergies, medications, and diagnoses although the corresponding textual descriptions may vary. Terminological systems are examples of semantic standards.

Terminological systems are systems that contain standardized terms pertaining to a certain domain. They are designed for collection, description, processing and presentation of terms, i.e. lexical items belonging to specialized domains. They play an important part in knowledge management and they are the keys to clear and consistent language usage within a domain. For many decades various terminological systems were developed for different domains using different structures ranging from strict hierarchies to semantic nets [22]. They provide an invaluable source of (structured) knowledge, and developed from single-purpose systems to systems serving a range of purposes, varying from recording patient information to providing decision support, and supporting epidemiological research [23]. To address this broadening range of purposes, medical terminological systems have grown in size and complexity [24]. The first terminological systems were developed as pre-defined systematic list and used to group together the medical terms reported by healthcare providers for statistical purposes [24, 25]. Contemporary terminological systems provide a broad range of concepts and a set of formal rules to manipulate them. The rules allow users to create new concepts based on already defined concepts. This functionality makes the range of concepts broader and therefore better facilitates data entry. New terminological systems are conceived for computer use and their typical complexity and evolution rate preclude presentation on paper [25].

One of the terminological systems which enable healthcare providers to record data at the appropriate level of granularity is SNOMED CT. This terminology provides the core general terminology for the patient information system and contains more than 311,000 active concepts with unique meanings and formal logic-based definitions organized into hierarchies. Its primary hierarchies include Clinical finding, Procedure, Observable entity, Body structure, etc [26]. SNOMED CT contains the semantic relationship IS_A within a single hierarchy and attribute relationships which connect concepts in different hierarchies e.g. Body structure with Clinical finding and Procedure [27]. Coding using SNOMED CT not only offers the facility to provide greater detail about a patient than was possible in previous coding schemes, it also allows for additional context information to be coded and associated with the patient.

Fully interoperable systems require a mutually agreed-upon set of data elements as well as standard terminologies and standard information models. Variance among the data sets that is not recognized can affect the information flow as well as the workflow. Agreed-upon datasets indicate what type of data should be collected in information systems. Together, the datasets and terminological systems provide re-usable content for systems that can be shared by standard information models [28]
1.3. Data collection in preoperative assessment

Preoperative assessment considers information from multiple sources that may include the patient’s medical records, interview, physical examination, and findings from medical tests and evaluations [13]. The main parts of the assessment are history taking and physical examination, focusing on risk factors for cardiac, pulmonary and infectious complications, and a determination of a patient's functional capacity [29]. The American Society of Anesthesiologists (ASA) believes that the assessment firstly of anesthetic risks associated with the patient’s medical conditions, therapies, alternative treatments, surgical and other procedures, and secondly of options for anesthetic techniques are essential components of basic anesthetic practice [13]. Further evaluation or laboratory testing may be required, depending on the patient's underlying medical condition and the planned procedure [30, 31]. With the collected data during the preoperative assessment, healthcare providers can develop a plan of treatment, identify and minimize risk factors, and involve support systems if necessary [11]. As the preoperative assessment is a multidisciplinary domain, involving at least nurses, anesthesiologists and surgeons, data should be collected in a standardized way to increase effective communication. Communication problems were reported as the main reason for incidents leading to planned processes not being followed [16]. An essential means to prevent miscommunication and reassessment is having an agreed-upon dataset. A defined dataset gives healthcare providers a clear statement about what should be collected. Moreover, it facilitates the flow of information between healthcare providers and patients and prevents information to be neglected by both sides. Implementation of a standardized dataset in AIMS will support healthcare providers in data collection and will facilitate implementation of clinical guidelines.

1.4. Clinical guidelines

Clinical guidelines are systematically developed statements designed to help healthcare providers and patients in making decisions about appropriate healthcare for specific circumstances [32]. They provide a common standard of care both within a healthcare organization and among different organizations. In general, clinical guidelines aim to describe appropriate care based on the best available scientific evidence and broad consensus, to reduce inappropriate variation in practice, improve patient outcomes and reduce costs of patient care [33, 34]. To achieve these goals, clinical guidelines should be provided at the point of care. Therefore, the paper-based guideline has to be translated into a computer interpretable format, a process called guideline formalization [35]. The guideline concepts should be represented by standard terminologies to support sharing, reusability and general interoperability.

1.5. Decision support systems

Simply collecting and retrieving data is only one reason to implement an AIMS. An ideal system should appropriately annotate the patient data and use specific combinations of information to provide clinical decision support [6]. Clinical decision support systems (CDSSs) are computer systems designed to support clinicians’ decision making about
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individual patients at the point of care when these decisions are being made [36]. Wyatt and Spiegelhalter proposed a more specific definition of CDSS: they stated that a CDSS is an active knowledge system that uses two or more items of patient data to generate case-specific advice [37]. A CDSS brings existing knowledge and relevant patient data to the point of care. It has the potential to make clinical guidelines available to physicians. Generally, CDSSs have the potential to aid clinicians in collecting relevant data, making clinical decisions, managing medical actions more effectively, and thereby making fewer practice errors, achieving a higher standard of care and reduced costs [6, 36]. To achieve these goals CDSSs should have the possibility to get the required data from the patient information system.

CDSSs should be seamlessly integrated in the clinical workflow and the patient information system [38, 39]. Integration of CDSSs with the patient information system requires standard information models and standard terminologies. Terminological systems facilitate the binding between the concepts used in the patient information system and the concepts defined in decision rules. If the system does not have access to a terminological system it is not possible to make use of terminological reasoning with the rules of a CDSS [40]. Thus, the rule “if a patient is obese, then anesthesia type and dose should be adjusted” has to be present in the system as many times as there are types of obesity, each rule differing in the mentioned type of obesity: “central obesity”, “Mauriac’s syndrome”, “buffalo obesity”, “drug-induced obesity”, etc. Moreover, if physicians use different synonyms to refer to one type of obesity, e.g. using terms “android fat distribution”, “truncal obesity”, or “fat body with thin limbs” to refer to the concept “central obesity”, new rules should be defined in the system as many times as the number of synonyms. In a terminological system all types of this condition are subsumed by the concept “obesity” and all synonyms of a concept are related to a single concept as descriptions thereof. Therefore, if an AIMS uses a terminological system, this system will be able to infer that a patient with condition “Mauriac’s syndrome” is obese and the CDSS will give the physician the required advice regarding anesthesia type and anesthetic dose during preoperative assessment. In this situation only one rule will be required to represent this recommendation, improving the readability of the knowledge base and easing its maintenance [40].

1.6. Interface terminology on SNOMED CT

Reference terminologies are systematic collections of concepts covering most areas of clinical information. They represent and aggregate the information that makes up a given medical domain’s conceptual knowledge and store this information in the form of terms, concept identifiers, and semantic relationships [41-43]. A reference terminology can provide a foundation upon which healthcare organizations, information system vendors, the insurance industry, government and others can aggregate and analyze data for the improvement of healthcare [44]. It is impractical to use a comprehensive reference terminology such as SNOMED CT including its large number of concepts for direct documentation of patient information. Specific applications tend to focus on a restricted set of SNOMED CT, such as terms related only to ophthalmology. These so-called interface
terminologies can be used to present relevant parts of the terminology, depending on the clinical context and local requirements. Interface terminologies are designed to facilitate the interaction between healthcare providers and structured medical information [45]. Interface terminologies generally consist of a rich set of flexible and colloquial phrases that can be used for clinical documentation [46, 47]. To create an interface terminology developers often select a subset of a reference terminology and tailor it to a specific setting. For example, for documentation of the preoperative assessment, a drop down list to select the past history of clinical findings in AIMS can be tailored to those histories that should be considered during the preoperative assessment. This will shield users from the complexity and large amount of concepts provided in a reference terminology and adapt easier to the user requirements. On the other hand, reference terminologies do not have the necessary coverage to be the exclusive content provider for the structured medical information. To overcome this problem, sometimes developers of interface terminologies have to add some new concepts to the pre-existing concepts to make the interface terminology complete. However, despite the advantages of interface terminologies there is no formal method for creating interface terminologies.

1.7. Research questions of this thesis

Healthcare providers should have an agreed-upon dataset for collecting the patient data in preoperative assessment. This dataset should be presented in a standardized format to facilitate data shareability and interaction of AIMS with existing patient information systems. This interaction is essential because many of the potential benefits, e.g. providing guideline-based decision support system regarding patient allergies, depend on computer systems communicating with each other [48]. This communication requires standardized data and will be facilitated by using standardized terminological systems. The preoperative dataset should contain concepts required to facilitate implementation of guideline-based decision support systems. The concepts defined in the dataset should be presented into the system by using an interface terminology providing preoperative assessment concepts. In this thesis the following research questions were addressed:

- Which data should be collected during preoperative assessment?
- Can SNOMED CT be used to represent concepts required to implement preoperative assessment guidelines?
- Do CDSSs described in the literature use standardized data, and which terminological systems were used by CDSSs for coding data?
- How can an interface terminology on SNOMED CT be constructed?

1.8. Outline of this thesis

After this introductory chapter, different studies addressing the above-mentioned research questions are described.

To get insight into the collected data during the preoperative assessment, to help us to design standardized content for the preoperative assessment part of AIMS, in chapter two
of this thesis we search the literature to see which data items are commonly collected during the preoperative assessment. As a first step toward data standardization, in this project we developed a core dataset for preoperative assessment, based on the insight obtained in the second chapter. The development process of this dataset is presented in **chapter three**. The designed subset is intended to be implemented in AIMSs to support healthcare providers in data collection and for other purposes. As we aim to use SNOMED CT as a comprehensive standard terminology for presentation of data in AIMSs, to implement the preoperative assessment guidelines in AIMS, in **chapter four** we investigate to what extent SNOMED CT covers concepts used in these guidelines. We also investigate why some of the guideline concepts can not be represented by SNOMED CT. In **chapter five**, we search the literature to investigate whether existing CDSSs used standardized data to invoke the system or generate advice. We also investigate which terminological systems have been used in CDSSs to code data. Moreover, in this chapter, we present a survey among authors of the studies on CDSSs to determine the obstacles of CDSS implementation. The aforementioned steps in the chapters two, three and four are fundamental steps in designing a SNOMED CT subset for preoperative assessment based on the developed dataset. In **chapter six** we develop a generic approach for constructing an interface terminology on SNOMED CT. To illustrate the developed approach we applied it to the domain of intensive care. This domain was chosen because firstly in the ICU domain recent and running projects on the application of SNOMED CT provide us with a good opportunity to test our developed approach [49-51]. Secondly, a majority of the ICU population consists of postoperative patients and for most of them ICU admission is planned based on preoperative assessment. In this way, more insight is gained in the full perioperative process. Finally, in **chapter seven** the results of the various studies are synthesized and discussed and future research is suggested.
References


Introduction


Chapter 1


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